# From Metrics and Influence to Telling the Scientific Story: Evaluating Sea Level Rise

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**Abstract**
Sea level rise is predicted to be one of the most studied fields in the coming decades. With some three billion people living in coastal communities around the world, sea level rise has the potential to affect nearly half the world's population. About 40% of the US population lives in or near a coastal community (NOAA, 2020b). Although the study of sea level rise began in the late 1800s, it has gained momentum in the last 20 years. An interdisciplinary group of scientists, engineers, and geologists in diverse university departments, such as Coastal Engineering, Geological Sciences, and Urban and Regional Planning are studying the various facets of this phenomenon. This paper identifies 1) the knowledge librarians need to understand the various metrics, and 2) how librarians can partner with scientific researchers to select relevant research impact strategies that will convey a compelling scientific story. This story can lead to future grant support, promotion and tenure awards, and perhaps to scientific policy changes.

**Keywords***:* Sea level rise, research impact, research metrics, scientific story.

## Background

With some three billion people living in coastal communities around the world, sea level rise has the potential to affect nearly half the world's population. Sea level began rising in the late 1800s, coinciding with the burning of coal, gas, and fossil fuel (Smithsonian & Team, 2018). Caused by thermal expansion of the oceans due to an increase in seawater temperature, as well as the melting of glacial ice, sea level is on the rise. With average year-round global temperatures increasing, glaciers are experiencing a disproportionate amount of melting at an accelerated rate (NOAA, 2019). Figure 1 shows that since 1880 global mean sea level has risen approximately 210-240 millimeters (mm) or 8 to 9 inches, with one-third of the rise occurring in the last 25 years (Lindsey, 2020).

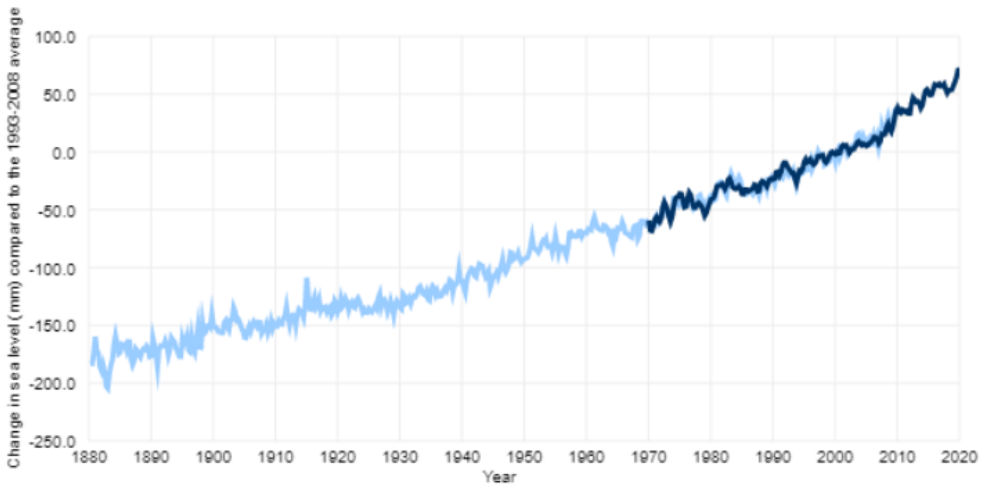


*Figure 1. Sea level rise since 1880 (Lindsey, 2020).*

Researchers have estimated rates of sea level rise with Douglas et al. (2001) seeing an increase since the middle of the mid-19th century. In October 2020, the world population exceeded 7.7 billion people (US Census, 2020)and it is estimated that nearly 40% of the world's population lives within 100 kilometers, or 62 miles, of a coastline that could potentially be affected by sea level rise (UN, 2007). Eight of the ten largest cities in the world are located by the coast (NOAA, 2019).

**Literature Review**

Globally, sea level rise as related to climate change is of great interest. Husain and Mushtaq (2015) conducted a research assessment analysis on climate change data related to environmental science and ecology that covered the five-year period from 2009 to 2013. Li et al. (2011) used a science citation index analysis to explore trends on global climate change research during the 18 years between 1992 and 2009. Both of these studies looked at the broader subject of climate change, versus that of focusing on sea level rise, which has more immediate and visible impacts to coastal communities. Nel et al. (2014) reviewed the status of sandy beach science and included a citation analysis on the published literature from 1950 through 2013. Social scientists are also studying sea level rise and potential impacts to populations (Bures and Kanapaux, 2011). The future economic impacts of sea level rise are staggering (Bosello et al., 2012).

The amount of sea level rise depends on location and estimates can be variable. In some ocean basins, sea level has risen dramatically, as much as 6-8 inches (15-20 centimeters) since the start of the satellite record in 1993 (Lindsey, 2020). Coastal communities will be at greater risk for flooding in the next several decades due to storm surges and high tides combined with sea level rise and land subsidence. It is predicted that the oceans will continue to warm and sea level will continue to rise for many centuries (NASA, 2020).

In the United States (US), approximately 39% of the population lived in highly populated coastal areas in 2010 (as of last US census), and that percentage is increasing. Sea level changes will vary by location but are expected to be highest in places like the northern Gulf of Mexico, especially in low-lying areas of Louisiana (NOAA, 2020a). However, in some places such as Alaska, the land surface is actually rising and, consequently, sea level is appearing to decrease. National Oceanic and Atmospheric Administration (NOAA) provides an interactive world map showing predicted sea level trends (https://tidesandcurrents.noaa.gov/sltrends/sltrends.html).

Along the U.S. coastline, flooding during high tide is 300% to 900% more frequent than 50 years ago (NOAA, 2019). Coastal communities, as all communities, require a complex network of infrastructure systems, including transportation, power generation, communication networks, fresh water distribution, and waste collection. But coastal communities have additional issues with which to contend, including storm impacts, flooding from increasingly higher tides, and salt water intrusion; problems all exacerbated by sea level rise. A convergence of scientists, engineers, and geologists from diverse disciplines including Coastal Engineering, Urban and Regional Planning, and Geological Sciences have been studying the various facets of this phenomenon. As expected, universities located in states with large coastal areas are conducting the majority of the research. With Florida's 8,436 miles of coastline, multiple schools, departments and institutes at UF are involved in sea level rise research (University of Florida, 2019). In Florida, sea level rise is predicted to negatively impact heavily populated areas such as Naples, Ft. Myers, Clearwater, Palm Beach, Miami and the Florida Keys (NOAA, 2020a). Places like Miami, Florida already see city streets routinely flooding during high tides.

Ongoing sea level rise will ensure that the study of shoreline responses and impacts will continue to be relevant. Beach erosion is a notable consequence of sea level rise and flooding of low-lying areas is another. The City of Miami already routinely experiences street flooding during high tides and the City of Miami Beach has set aside $100 million to raise roadbeds, install pumps, and modify water mains and sewer conveyances (Flechas, 2017).

The University of Florida (UF) has a long history in research on sea level rise. In 1962, former UF professor Per Bruun, who was chair of the Department of Coastal Engineering from the late 1950's to 1966 (Hager, 2009), authored a now classic paper entitled "Sea level rise as a cause of shore erosion" in the 1962 Proceedings of the American Society of Civil Engineers, Waterways and Harbors Division (Bruun, 1962). In this paper, Bruun identified and described what is now recognized as a fundamental relationship between sea level rise and shoreline erosion. The Bruun theory, as it was named by Schwartz (1967) but now commonly called the Bruun Rule (for example, see Bruun, 1988 or Kerans and Cartwright, 2016), holds that an open, sandy beach coastline will retreat landward some one hundred times the vertical extent of sea level rise. This means that even a modest sea level rise causes substantial shoreline retreat or even the complete disappearance of beaches in situations where the beaches are backed by hard structures or cliffs instead of dunes. Since its original publication, this seminal article has been cited some 2,247 times (Google Scholar, accessed October 27, 2020). The fact that Bruun (1962) was cited some 90 times in 2018 alone, 57 years after its original publication, suggests that the Bruun Rule has continuing relevance in sea level rise research.

More accurate predictions for future sea level rise are predicated on an understanding of past episodes of sea level fluctuation. The UF Department of Geological Sciences is active in this line of research, working with international groups to investigate the geological record of sea level rise and changes in ice sheet mass, which is used to predict future sea level rise (Dutton et al., 2015).

**Purpose**

The purpose of our research was to determine the research metrics and impact at UF related to the study of sea level rise. Research impact can be determined at the journal, article and author levels. This research analyzes the impact of the articles written by UF scholars. The multidisciplinary approach to this scholarship leads to three questions:

1. What fields are publishing on sea level rise?
2. Where is the relevant literature being published?
3. What is the correlation between article citations and grant funding?

**Methodology**

To answer these questions, it was determined to use the vendor Clarivate Analytics Web of Science (WoS) Core Collection to which the UF Libraries has a subscription. The WoS Core Collection provides basic metrics but is limited in scope, breadth and depth of how to cross reference data sets. Clarivate Analytics sells INCITES as a separate research impact tool within the Web of Science Core Collection. To determine research impact using only the Core Collection is labor intensive and some features are not available. Using INCITES allows the researcher to conduct in-depth searching for impact that produces comprehensive picture of overall impact at the world, national, discipline and institutional levels, and to compare to peer universities both regionally and globally, and to find and analyze collaborations and partnerships. The UF libraries do not currently subscribe to INCITES; however the sales representative provided a 30-day free trial.  INCITES uses imported datasets from searches conducted in the WoS Core Collection.  Table 1 compares the features of the WoS Core Collection to INCITES.

| **Features** | **Web of Science Core Collection** | **Web of Science INCITES** |
|---|---|---|
| Content | 74.8M records, 21,100 active titles from multiple publishers | Core Collection only; 20 custom datasets |
| Scope of Coverage: Date Range | 1900s to present | 1980-present. 2 months behind the Core Collection content. |
| Update Frequency | Daily, Monday-Friday | Monthly |

*Table 1. Comparison of Web of Science Core Collection to Web of Science INCITES.*

The search parameters were as broad as possible to capture all relevant concepts of sea level rise. A topic search that includes title, abstract, author keywords, and KeyWords Plus, a trademark of Clarivate Analytics for “sea level rise” OR “sea level” OR “sea level rising”. Library of Congress the formal subject heading is “sea level” with variants of “mean sea level” and “sea level rise” in the GC89-GC90 Library of Congress classification and is also recognized by the USDA National Agricultural Library. For this study, the variant “sea level rise” will be used exclusively. The publication year range was from 2010-2019.  The document type was limited to original research, excluding review articles, book chapters, conference proceedings, and other commentaries. The organization was limited to the “University of Florida.”

**Results**

Web of Science: This search resulted in a total of 28,438 articles in the Core Collection. Adding the parameters of the search strategy yielded 219 original articles with 3 highly cited in the field, and 61 articles are available via open access. These results can be further analyzed in the Core Collection feature Analyze Results, but they lack the functionality of the cross referencing of data needed to determine research impact. The dataset from the Core Collection search results were exported into INCITES.

***Question 1. What fields are publishing on sea level rise?***

The majority of the scholarship is from the multidisciplinary field of geosciences, followed by environmental sciences, physical geography, and ecology. Figure 2 shows the number of articles published in a specific research area, or the fields of collaboration between UF researchers and their colleagues around the world. Therefore, UF researchers have published 60 original research articles with colleagues in the geosciences. Table 2 shows the impact of these articles by the number of times the articles have been cited. This is a good overall assessment of which fields are collaborating and producing the most research related to sea level rise.

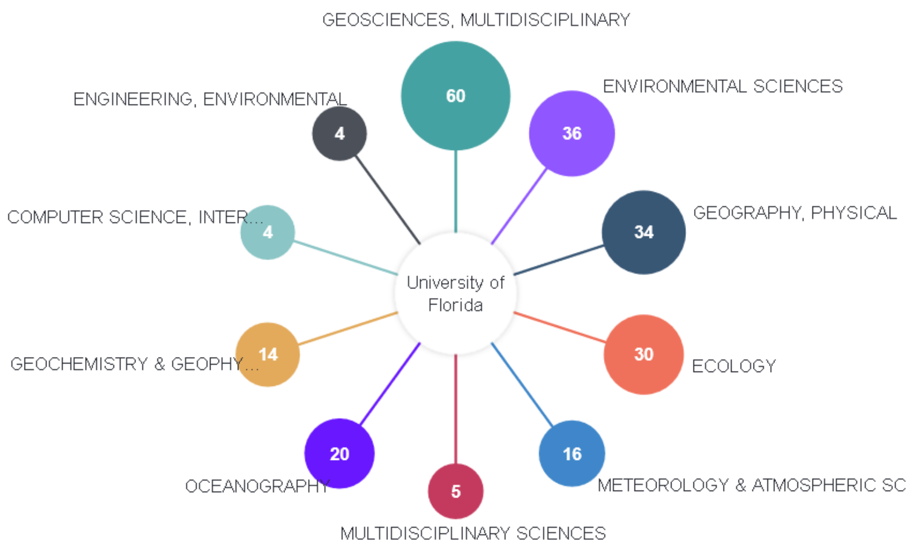


*Figure 2. Fields with the most UF researchers and world collaborations.*

With INCITES, there are many variables that must be taken into consideration when measuring impact. To answer the question about which fields are publishing on sea level rise, an analysis of research areas, number of published research articles, number of times these articles have been cited by other scholars, and the citation impact for the institution, worldwide collaborations is demonstrated.

| **Research Area** | **# of WoS Articles** | **Category Normalized Citation Impact** | **Times Cited** | **% of Articles Cited** |
|---|---|---|---|---|
| Geosciences, Multidisciplinary | 60 | 1.4 | 1187 | 87 |
| Environmental Sciences | 36 | 1.1 | 720 | 92 |
| Geography, Physical | 34 | 1.0 | 560 | 88 |
| Ecology | 30 | 0.8 | 447 | 87 |
| Meteorology & Atmospheric Sciences | 16 | 1.5 | 376 | 100 |
| Multidisciplinary Sciences | 5 | 2.7 | 330 | 100 |
| Oceanography | 20 | 1.3 | 271 | 90 |
| Geochemistry & Geophysics | 14 | 1.6 | 252 | 79 |
| Computer Science, Interdisciplinary Applications | 4 | 2.5 | 172 | 100 |
| Engineering, Environmental | 4 | 1.7 | 172 | 100 |

*Table 2. Impact of the published original research.*

**CNCI.** The Category Normalized Citation Impact (CNCI) is calculated by dividing the actual count of citing items by the expected citation rate with the same document type, year of publication and subject area. The research articles (Table 2) have been assigned to more than one subject area (by WoS). The CNCI of these articles is the average of the CNCI values for all the documents in the research area. Therefore, the CNCI is an ideal indicator for benchmarking at all organizational levels including the author, institution, region (INCITES, 2020).

The CNCI value is the average of the values for each of the papers, represented as:

$$CNCI_i = \frac{\sum_i CNCI_{each\ paper}}{p_i}$$

e = the expected citation rate or baseline, c = Times Cited, p = the number of papers, f = the field or subject area, t = year, d = document type, n = the number of subjects a paper is assigned to and i = the entity being evaluated (institution, country/region, person, etc) (INCITES, 2020).

**Times Cited/% Cited**. This number represents the number of times the articles in the research areas have been cited by other scholars. For example, in the Geosciences, 87% of the articles have been cited 1187 times. These figures are presented in the CNCI calculation. Another example is the Multidisciplinary Sciences where there are five published articles, but the impact of those articles is very high (CNCI=2.7) because each article has been cited (100%), with a total of 330 cites. Therefore, it’s not only the number of articles being published but the influence of those articles.

***Question 2. Where is the relevant literature being published?***
Table 3 shows where highly cited articles by UF researchers are being published. An article published in 2012 in the journal *Geological Sciences of America Bulletin* was cited 202 times. Only looking at original research, we discovered that out of the 60 articles published, these articles were cited approximately 1130 times. The highest cited articles are found in the journals listed in Table 3. When analyzing the impact factor of these journals, the articles on sea level rise are being publishing in high impact journals with evidence of being cited frequently.

| Source | Research Area | Publication Date | Times Cited |
|---|---|---|---|
| *Geological Society of America Bulletin* | Geosciences, Multidisciplinary | 2012 | 202 |
| *Journal of Coastal Research* | Geography, Physical; Geosciences, Multidisciplinary; Environmental Sciences | 2011 | 103 |
| *Quaternary Science Reviews* | Geosciences, Multidisciplinary; Geography, Physical | 2010 | 102 |
| | | 2015 | 49 |
| *Geophysical Research Letters* | Geosciences, Multidisciplinary | 2011 | 79 |
| | | 2012 | 43 |
| *Natural Hazards* | Water Resources; Geosciences, Multidisciplinary; Meteorology & Atmospheric Sciences | 2014 | 62 |
| *Paleoceanography* | Paleontology; Oceanography; Geosciences, Multidisciplinary | 2011 | 56 |
| *Climate of the Past* | Geosciences, Multidisciplinary; Meteorology & Atmospheric Sciences | 2016 | 46 |
| *Marine Geology* | Oceanography; Geosciences, Multidisciplinary | 2013 | 43 |

*Table 3. Publications and times cited of UF researchers and their world collaborators.*

***Question 3. What is the correlation between article citations and grant funding?***
The UF researchers are participating on grants from the NSF, Australian Research Council (ARC), National Geographic Society (NGS), Australian National University, Smithsonian Institute, US Geological Society, UF, and NOAA. One requirement when writing the grant is to estimate the number of publications produced, and where the applicants will publish.

Figure 3 shows the correlation of times cited and funding organizations and the number of publications indexed in WoS. For 82 granting agencies worldwide, 255 articles were written and those articles have been cited 5,997 times. The NSF has 78 articles in WoS. From WoS, the dataset in INCITES identified 78 articles, cited 1124 times, with a normalized citation impact of 1.38. Next, ARC had 8 articles from WoS INCITES for 364 times cited with a normalized citation impact of 2.9. NGS also had 8 articles identified, with 316 times cited, and a normalization citation impact of 2.14. This shows that the ARC had a bigger impact than NGS even though they had the same number of articles.

UF researchers received grant funding from 60 agencies which produced 94 articles. Those 94 articles were cited 1,936 times. Most notable was the National Science Foundation (NSF), for which 11 articles indexed in WoS. When analyzed in INCITES, the researchers were cited 143 times with a normalized citation impact of 1.35. Another example is National Environmental Research Council (NERC), which had five articles indexed in WoS. When analyzed in INCITES, they were cited 95 times with a normalized citation impact of 2.6.

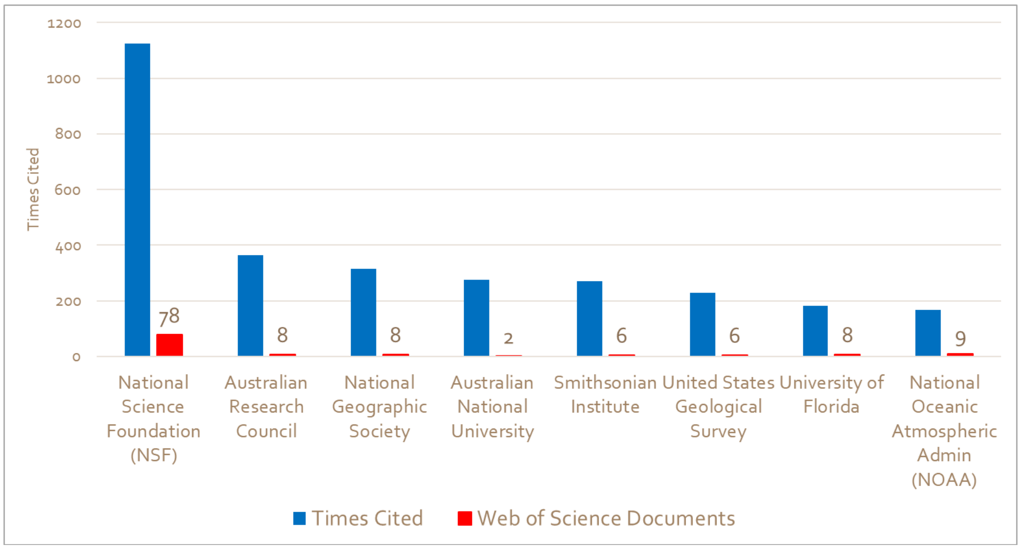


*Figure 3. Correlation of times cited and funding organizations.*

**Discussion**
Making research discoverable is a key component that can lead to future grant support, promotion and tenure awards, and perhaps to scientific policy changes. An example from UF is Dr. Andrea Dutton, a researcher in the Geological Sciences Department. Her 2012 article in *Science* has been cited 233 times. Social media such as Twitter posts are a way of broadening impact and reaching a larger maybe untapped audience. Scholarly articles mentioned on Twitter are communicated to a diverse group of readers. Figure 4 shows a recent post on Twitter by the UF Department of Geological Sciences regarding a study in Greenland about climate change. “Likes” on Twitter is a means of measuring impact that is both broader and more immediate than citation counts and is gaining popularity in research as an evaluation and assessment tool. Alternative metrics pull the data from Cross Ref, publishers, and vendors such as Clarivate Analytics. Scholars should use this opportunity to provide fast accessibility to their research to audiences that may not have subscriptions to the articles that are not open access. This promotion of research to a wide audience creates a level of trust between science and the reader on a global level.

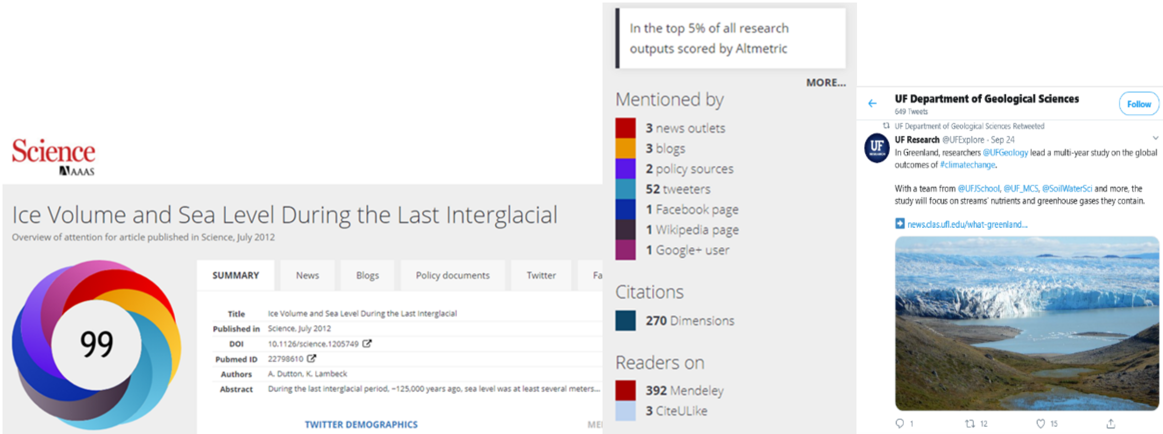


*Figure 4. Social media posts.*

## Conclusion

How can librarians participate in telling the scientific story? Librarians can guide researchers on where to publish. Through offering workshops at pivotal times of the year (i.e., grants, promotion, tenure), librarians can guide their faculty through the often-complex world of grant writing, understanding journal citation reports, measuring productivity of research, and assessing citation impact. By identifying networking and collaboration efforts, librarians can help their faculty make those important connections. Their knowledge of the culture of the disciplines, departments and institutions can be an asset to their institutions. By helping to promote the researcher's visibility for their research output to generate interest through social media, librarians provide that avenue for faculty to tell their scientific story.

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